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IMPROVEMENT OF MICROTURBINE GENERATOR OUTPUT VOLTAGE USING MATRIX CONVERTER

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ABSTRACT

In distributed generation (DG) Microturbine-generator is used for different applications. Due to its high speed and low inertia, frequency converter is used to deliver power at 50/60Hz. In this paper, implementation of Matrix Converter is interfaced to microturbine-generator. The simulation results are shown by using matrix converter, to enhance output voltage.

KEYWORDS: Matrix Converter (MC), Harmonics, Microturbine-Generator (MTG), Bi-Directional Switch, Converter

INTRODUCTION

In recent years, application of Distributed Generation (DG) sources has increased significantly. Microturbine-Generator (MTG) is well suitable for different distributed generation applications, because it can be connected in parallel to serve larger loads, can provide reliable power and has low-emission. MTGs have the rated power from 30 to 250 kW, generating electricity in ac, and they can be installed in isolated conditions or synchronized with the electrical utility. MTGs are available as single-shaft or split-shaft units. Single-shaft unit is a high-speed synchronous machine with the compressor and turbine mounted on the same shaft. While, the split-shaft design uses a power turbine rotating at 3000 rpm and a conventional generator connected via a gearbox for speed multiplication [2]. In this paper, the single-shaft structure is considered. Single-shaft MTGs are usually composed of gas turbines, electric power generators (usually a permanent magnet synchronous generator-PMSG), frequency converters (interface converters), and protection and control systems (Figure 1). The interface converter is used to convert PMSG output voltage frequency (high frequency) to power system (50/60 Hz) frequency.

MICROTURBINE MODELING

The modeling of microturbine has been done in Matlab/Simulink (Figure 2). As can be seen in Figure 2, the model is made up of speed controller, acceleration controller, temperature controller and fuel system (including valve positioner and actuator). The exhaust temperature function *f1* and torque function *f2* is given by:

$$f1 = T_R - 700(1 - W_{f1}) + 550(1 - \omega) \tag{1}$$

$$f2 = 1.3\,(W_{f2} - 0.23) + 0.5\,(1 - \omega) \tag{2}$$

Where denotes turbine speed, W_{f1} and W_{f2} are fuel flows signals, and T_R denotes rated exhaust temperature.

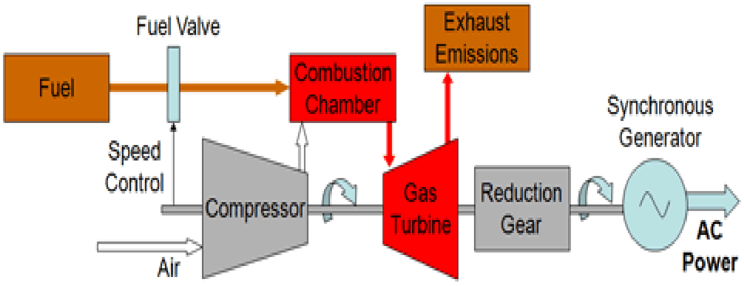


Figure 1: Block Diagram of a Single-Shaft MTG

MATRIX CONVERTER (MC)

MC is an array of controlled semiconductor switches that connects directly the three-phase source to the three-phase load. In the other words, MC performs a direct AC/AC conversion. While, AC/AC conversion is conventionally achieved by a rectifier stage, a dc link and an inverter stage. Since, in the MC the switching is performed on sinusoidal waveforms, the output voltage quality can be better than the conventional rectifier-inverter structure. Also, there is no dc-link (large energy storage element) in MC. So, the MC is more compact compared to conventional AC/AC converters [5, 6].

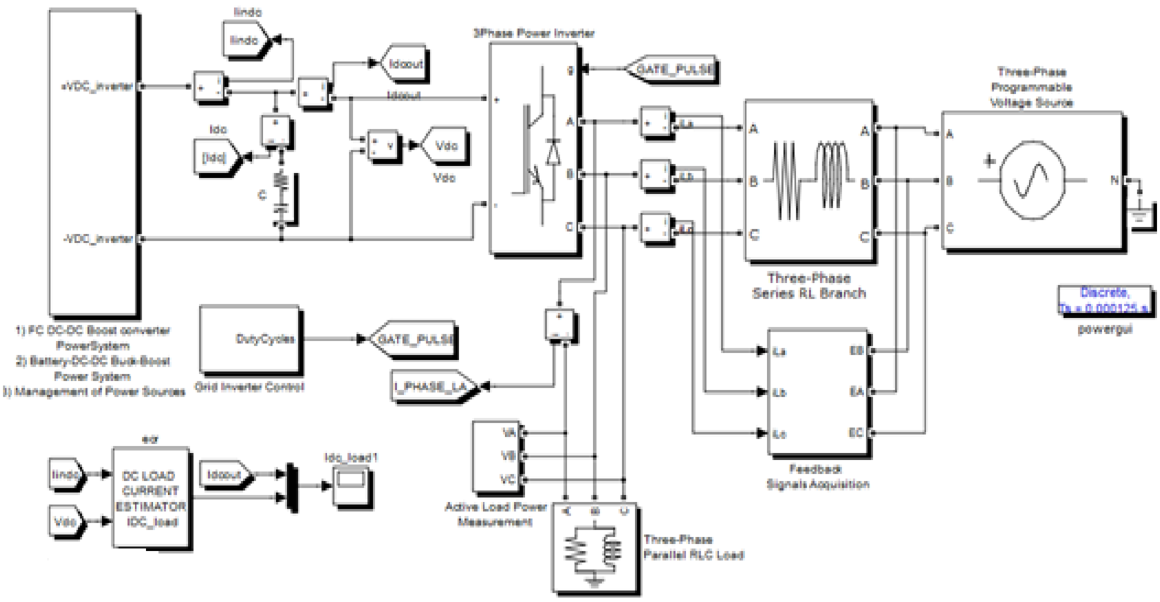


Figure 2: Modelling of Micro Turbine Generator Using Mat Lab/Simulink

A common matrix converter structure consisting of 3x3 switches is shown in Figure 3. As can be seen, it connects a three-phase voltage source to a three-phase load [6]. The matrix converter requires a bidirectional switch capable of blocking voltage and conducting current in both directions. Unfortunately, there are no such devices currently available, so discrete devices need to be used to construct suitable switch cells. In this paper, the common-emitter back to back structure is used as bidirectional switch. The Simulink model of this switch is shown in Figure 4.

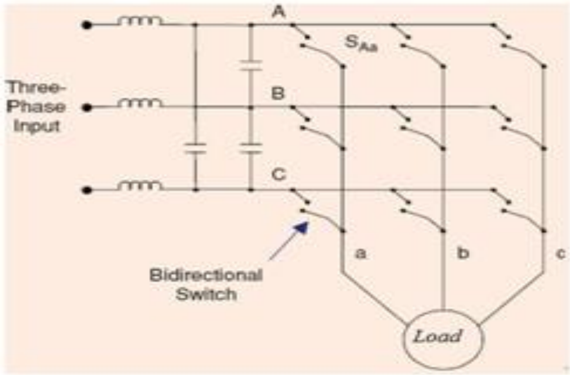


Figure 3: Basic MC Structure

In order to derive modulation rules, it is also necessary to consider the switching pattern that is employed. This typically follows a form similar to that shown in Figure 5. By considering that the bidirectional power switches work with high switching frequency, a low-frequency output voltage of variable amplitude and frequency can be generated by modulating the duty cycle of the switches using their respective switching functions.

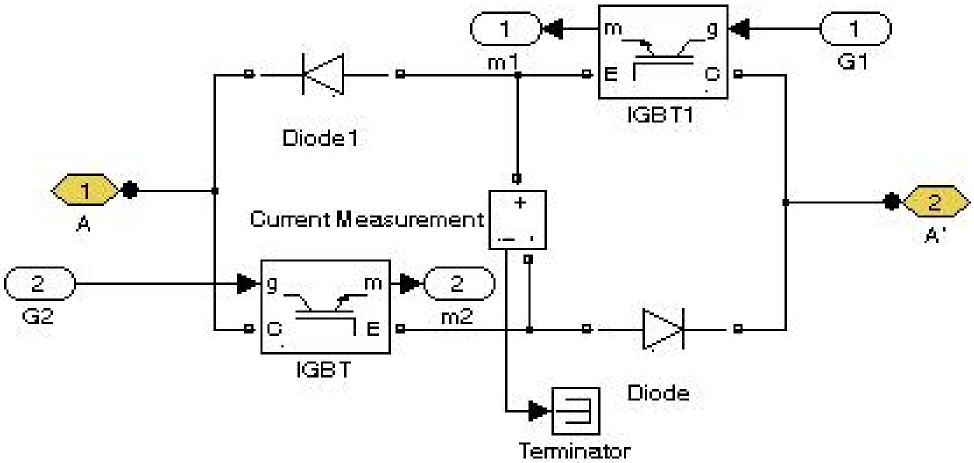


Figure 4: Simulink Model of Bidirectional Switch

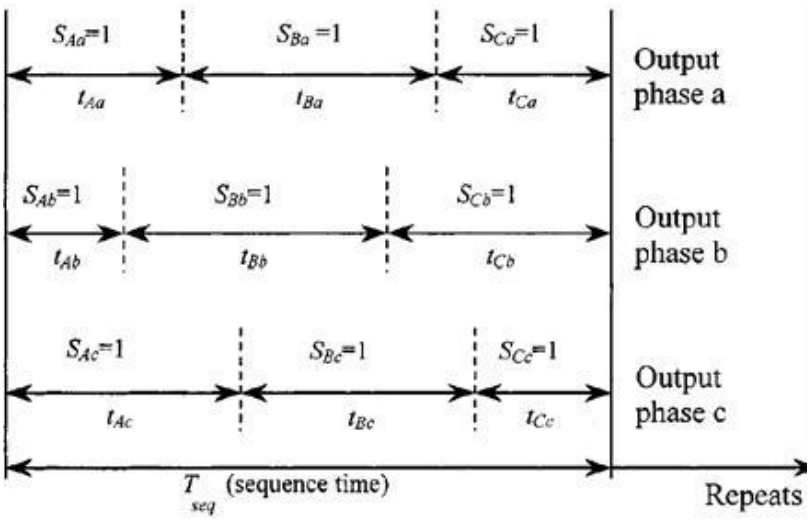


Figure 5: Switching Pattern

SIMULATION RESULTS

In this section, the MTG is simulated in Matlab/Simulink. The model of PMSG available at Simulink library is used for generator simulation. This PMSG has 8 poles and its rated power is 30kW. In simulations, the focus will be on comparison of output voltage quality of two MTG interface converters (matrix converter and conventional rectifier-inverter structure). In order to perform a true comparison, switching frequency of both converters is set to 5 kHz and output LC filters parameters are chosen to be the same. The block diagram of the simulated system is shown in Figure 6. The reference speed of the MTG is set to 45000 rpm. At first, The RLC load is 0.2 pu. Then, at t=14sec, the load has a step increase to 0.8 pu. The torque response of the microturbine is compared with the load demand in Figure 7. It can be seen that the torque has a good convergence. Also, speed of MTG is shown in Figure 8. As it can be observed, the speed converges to its reference value, too.

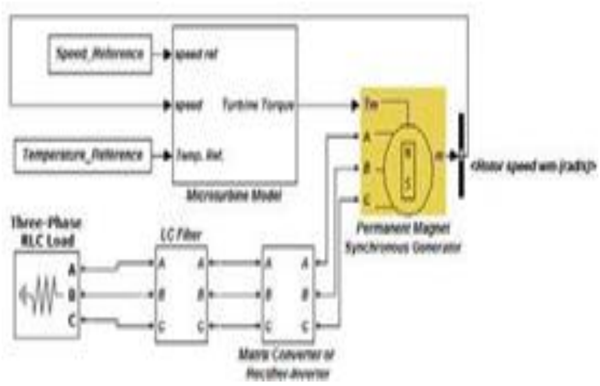


Figure 6: Simulated System

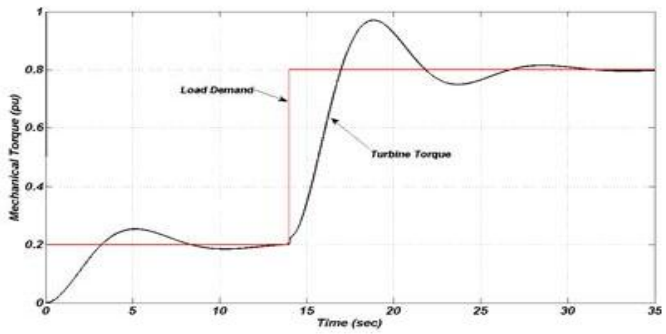


Figure 7: Mechanical Torque of MTG

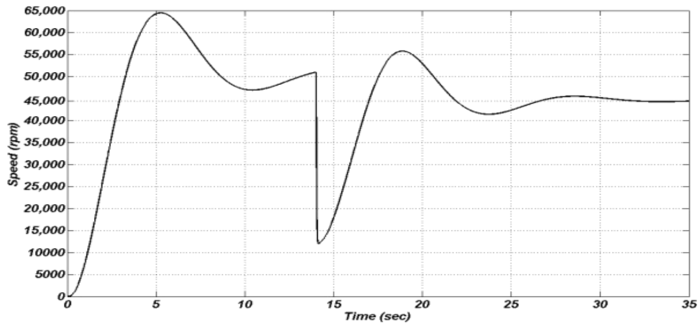
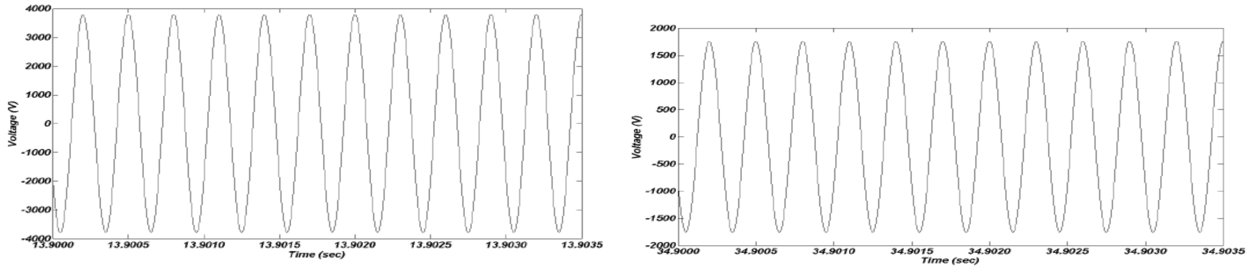


Figure 8: Speed of MTG



(a) **(b)**

Figure 9: PMSG Output Voltage: (a) Load= 0.2 pu (b) Load=0.8 pu

At this speed, the output frequency of the PMSG is 3000Hz and must be converted to power system frequency (60Hz). As it is mentioned earlier, it can be achieved using matrix converter or conventional rectifier-inverter structure. In Figures 9(a) and 9(b), PMSG output phase-a voltages at 0.2 pu and 0.8 pu loads are shown. Matrix and conventional converters operate on these load voltages to construct a 60Hz, 440V (p-p) output voltage. Output waveforms of these converters before filtering are shown in Figures 10 and 11, respectively.

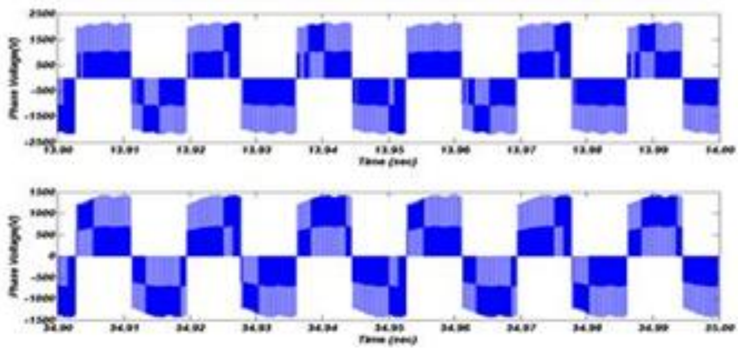


Figure 10: MC Output Voltage: Load= 0.2 pu (top) Load=0.8 pu (Bottom)

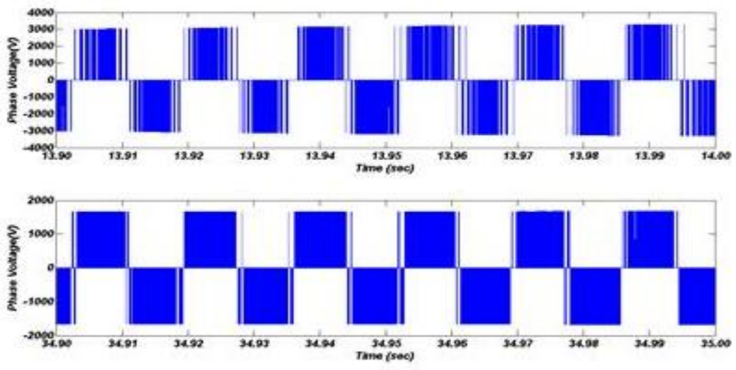


Figure 11: Conventional Converter Output Voltage: Load= 0.2 pu (top) Load=0.8 pu (Bottom)

These voltages are filtered by the LC filter to construct the load terminal voltages. Figures 12 and 13 show the filtered voltages waveforms. As it can be seen, the voltage THD values (5.5% and 4.5% for 0.2 and 0.8 pu loads) using MC are less than the ones in the case of conventional rectifier-inverter structure (7.2% and 6.5% for 0.2 and 0.8 pu loads).

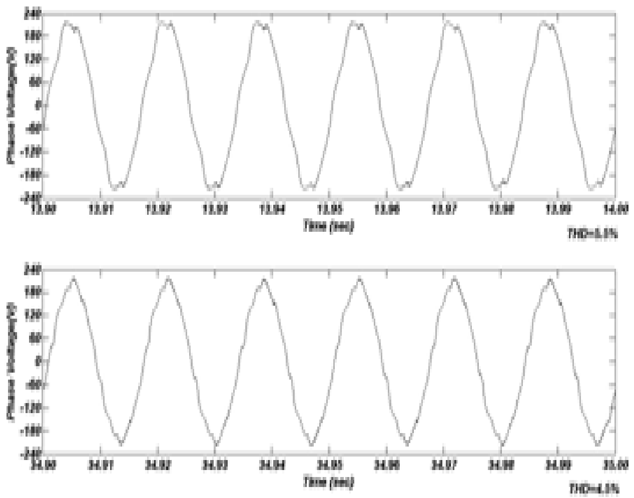


Figure 12: Load Terminal Voltage Using MC: Load= 0.2 pu (Top) Load=0.8 pu (Bottom)

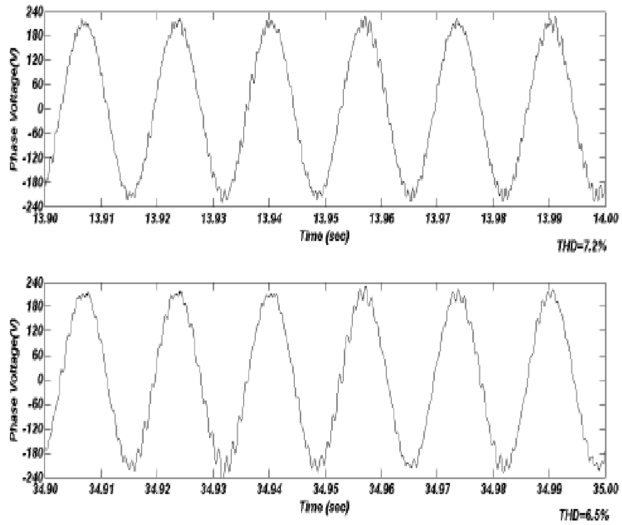


Figure 13: Load Terminal Voltage Using Conventional Converter: Load= 0.2 pu (Top) Load=0.8 pu (Bottom)

CONCLUSIONS

In this paper, application of the matrix converter as output frequency converter in microturbine-generator is addressed. Comparison of simulation results of MTG using matrix and conventional interface converters demonstrated the ability of MC to deliver a higher-quality voltage to the load.

Also, it is worthy to be noted that through application of MC the large dc link capacitor which is common in the rectifier-inverter structure is omitted. So, the interface converter can be more compact and less expensive.

REFERENCES

1. E. F. Pavinatto, M. B. Peres, P. D. Reis, L. S. Pereira, and F. P. Salles, “Use of microturbines in remote isolated oil and gas facilities in Brazil”, IEEE Ind. Appl. Mag., pp. 62-68, Nov./Dec. 2008.
2. A. K. Saha, S. Chowdhury, S. P. Chowdhury, and P. A. Crossley, “Modeling and performance analysis of a microturbine as a distributed energy resource”, IEEE Trans. Energy Conv., vol. 24, no. 2, pp. 529-538, Jun. 2009.

3. T. Yu, J. Tong, and K. W. Chan, “Study on microturbine as a back-up power supply for power grid black-start”, IEEE Int. Conf. 2009.

4. R. Noroozian, M. Abedi, G. B. Gharehpetian, and S. H. Hosseini, “Modelling and simulation of microturbine generation system for on-grid and off-grid operation modes”, Int.l Conf. on Renewable Energies and Power Quality (ICREPQ’09), Apr. 2009.

5. P. W. Wheeler, J. Rodriguez, J. C. Clare, L. Empringham, and A. Weinstein, “Matrix Converters: A Technology Review”, IEEE Trans. Ind. Elec., vol. 49, no. 2, pp. 276-288, Apr. 2002.

6. P. W. Wheeler, J. C. Clare, L. Empringham, M. Bland, and K. Kerris, “A vector-controlled MCT matrix converter induction motor drive with minimized commutation time and enhanced waveform quality”, IEEE Ind. Appl. Mag., pp. 59-65, Jan./Feb. 2004